Arterial grafts balance survival between incomplete and complete revascularization: A series of 1000 consecutive coronary artery bypass graft patients with 98% arterial grafts

Teresa M. Kieser, MD,[a] Helen J. Curran, MD,[b] M. Sarah Rose, PhD,[a] Colleen M. Norris, PhD,[c] and Michelle M. Graham, MD[c]

Objective: Coronary artery bypass grafting (CABG) with incomplete revascularization (ICR) is thought to decrease survival. We studied the survival of patients with ICR undergoing total arterial grafting.

Methods: In a consecutive series of all-comer 1000 patients with isolated CABG, operative and midterm survival were assessed for patients undergoing complete versus ICR, with odds ratios and hazard ratios, adjusted for European System for Cardiac Operative Risk Evaluation category, CABG urgency, age, and comorbidities.

Results: In this series of 1000 patients with 98% arterial grafts (2922 arterial, 59 vein grafts), 73% of patients with multivessel disease received bilateral internal mammary artery grafts. ICR occurred in 140 patients (14%). Operative mortality was 3.8% overall, 8.6% for patients with ICR, and 3.2% for patients with complete revascularization ($P = .008$). For operative mortality using multivariable logistic regression, after controlling for European System for Cardiac Operative Risk Evaluation category ($P < .001$) and CABG urgency ($P = .03$), there was no evidence of a statistically significant increased risk of death due to ICR (odds ratio, 1.73; 95% confidence interval, 0.80-3.77). For midterm follow-up (median, 54 months [interquartile range, 27-85 months]), after controlling for European System for Cardiac Operative Risk Evaluation category ($P < .001$) and comorbidities ($P = .017$) there was a significant interaction between age ≥ 80 years and ICR ($P = .017$) in predicting mortality. The adjusted hazard ratio associated with ICR for patients older than age 80 years was 5.7 (95% confidence interval, 1.8-18.0) versus 1.2 (95% confidence interval, 0.7-2.1) for younger patients.

Conclusions: This is the first study to suggest that ICR in patients with mostly arterial grafts is not associated with decreased survival perioperatively and at midterm in patients younger than age 80 years. Arterial grafting, because of longevity, may balance survival between complete revascularization and ICR. (J Thorac Cardiovasc Surg 2014;147:75-84)

The concept of complete revascularization (CR) in coronary artery bypass graft (CABG) surgery portending to improved patient outcomes was first espoused by McNeer and colleagues in 1974.[1] This gold standard may not be applicable today because data suggesting the benefits of CR included young, stable patients, first-time procedures, and predominantly vein grafting.[1] Newer studies are needed to evaluate contemporary CABG surgery, including use of total arterial grafting; off-pump CABG; and revascularization procedures in older, sicker patients. The goal of our study was to determine if there was a survival advantage of completely revascularized patients compared with ICR in a patient cohort with predominantly (98%) arterial grafting. We hypothesized that the long-term advantage of arterial grafts would potentially counteract the reduced survival of ICR in an all-comer group of CABG patients.

METHODS

From July 2003, to October 2012, total arterial grafting was performed where possible in all patients by 1 surgeon at a high volume academic tertiary care center. Patients were divided into 2 groups: Those in whom revascularization was complete and those in whom it was not.

All patients were entered into the Alberta Provincial Program for Outcome Assessment in Coronary Heart Disease study,[2] a prospective data collection initiative in the province of Alberta, Canada, since 1995. Patients are enrolled at initial cardiac catheterization and are followed to assess long-term survival and repeat revascularization with percutaneous coronary intervention (PCI) or CABG. Mortality is verified by linkage to Alberta Vital Statistics. All study patients were also entered into a prospective surgical database, recording patient demographics and relevant surgical data. This study was approved by our institution's research ethics board.

Angiogram and operative reports, and office charts of each patient were independently reviewed by both an interventional cardiologist and a cardiac surgeon to determine completeness of the revascularization. Revascularization was considered complete when all diseased arterial territories in

From the Libin Cardiovascular Institute of Alberta,[a] University of Calgary, Calgary, Alberta, Canada; Dalhousie University,[b] Halifax, Nova Scotia, Canada; and Mazankowski Alberta Heart Institute,[c] University of Alberta, Edmonton, Alberta, Canada.

Disclosures: Authors have nothing to disclose with regard to commercial support.

Read at the 93rd Annual Meeting of The American Association for Thoracic Surgery, Minneapolis, Minnesota, May 4-8, 2013.

Received for publication May 11, 2013; revisions received July 2, 2013; accepted for publication Aug 9, 2013; available ahead of print Sept 30, 2013.

Address for reprints: Teresa M. Kieser, MD, FRCSC, FACS, Department of Cardiac Sciences, Calgary Health Region Foothills Medical Centre, 1403 29th St NW, Calgary, Alberta, T2N2T9, Canada (E-mail: t.kieserprieur@ucalgary.ca).

0022-5223/$36.00

http://dx.doi.org/10.1016/j.jtcvs.2013.08.003

Abbreviations and Acronyms

CABG = coronary artery bypass graft
CIRC = circumflex artery
CR = complete revascularization
EuroSCORE = European System for Cardiac Operative Risk Evaluation
FFR = fractional-flow reserve
ICR = incomplete revascularization
IMA = internal mammary artery
LAD = left anterior descending
PCI = percutaneous coronary intervention
RCA = right coronary artery

left anterior descending (LAD) artery, circumflex artery (CIRC), and right coronary artery (RCA) regions, with ≥70% stenosis—or ≥50% in the left main artery—received at least 1 bypass graft for coronary arteries measuring >1 mm in diameter. Left main revascularization was considered complete if grafts were placed to the LAD and CIRC.

Five categories of reasons for incomplete revascularization (ICR) were obtained from operative reports: small vessel (<1 mm diameter), diffuse disease precluding healthy anastomosis, coronary artery inaccessible for grafting (location in the atrioventricular groove), infarcted territory (akinetic wall, thinned segment, or nonviable myocardium), technical problems (adhesions in reoperative surgery, high-risk or porcelain aorta needing off-pump procedure).

Surgery Details

All operations were performed off- or on-pump. For on-pump procedures, we used intermittent antegrade blood cardioplegia and systemic hypothermia to 32°C. Off-pump CABG was performed with the Octopus stabilizing device (Medtronic, Inc, Minneapolis, Minn). Internal mammary artery (IMA) conduits were harvested in a skeletonized manner, with the left IMA anastomosed to the LAD and the right IMA to either the CIRC or RCA. IMAs were used mostly as in-situ grafts and were wrapped in papaverine-soaked gauze after harvesting. High spinal anesthesia (local anesthetic and opioid) supplemented by light general anesthesia was used. Intraoperative transesophageal echocardiography was used except where contraindicated. Long-acting nitrates were used postoperatively for 6 weeks in only patients with radial artery grafts.

Statistical Analysis Methods

Descriptive analysis. Descriptive statistics (Table 1) for categorical variables and the means ± standard deviation for normally distributed continuous variables and the median and interquartile range (IQR) for non-normally distributed variables were provided for all patients. Comparisons of baseline variables were made between patients who experienced ICR and those who did not, only in patients with multivessel disease (single-vessel disease patients by virtue of their inability to be incompletely revascularized were excluded) (Table 2). Comparisons were made using the Fisher exact test for categorical variables and the *t* test (for normally distributed) or Wilcoxon signed rank tests (for non-normally distributed) continuous variables.

Regression modeling strategy for both logistic and proportional hazards regression. Initially we used individual regression models for each variable in Table 1 to examine if they were significant predictors of outcome. The functional form for continuous variables was examined using residuals analysis and if nonlinearity was detected, suitable transformations were used or the variable was categorized using appropriate cut-points to aid interpretation of the model. Next we entered each variable in Table 1 into a regression model, including the ICR variable to assess for confounding. In the event of evidence of confounding we examined the possibility of an interaction between ICR and that variable. All variables significant at $P < .2$ in the individual regression, interactions significant at $P < .20$ and variables that appeared to be confounding were entered into a multivariable logistic regression model. The possibility of collinearity was examined between predictor variables; the inclusion of highly correlated predictor variables that might cause instability of the model was avoided. To avoid overfitting, we reduced the model by excluding nonsignificant variables (starting with the largest *P* value), provided that this did not change the estimate of the primary predictor variable, ICR (ie, the excluded variable did not contribute to confounding). This process continued until the appropriate number of degrees of freedom in the model was retained ($n/10$) where n is the number deaths in each model.

Logistic regression was used to assess operative mortality, with the effect of univariate predictors presented as odds ratios (ORs) with 95% confidence intervals (CIs) and estimates of 30-day mortality for each level of the variable. The multivariable model was presented as ORs and adjusted 30-day morality rates were estimated using predictive margins.

Midterm survival was estimated in the operative-survivor patient population, using proportional hazards regression. Out-of-province patients not available for follow-up were excluded. The assumption for proportional hazards was examined using Schoenfeld residuals.[3]

RESULTS

Study Population

From July 18, 2003, to February 2, 2013, 1000 consecutive patients underwent CABG surgery with 98% (2922 out of 2981) arterial grafts. Excluding 59 patients (6%) with single vessel coronary artery disease, 73% (686 out of 941) of patients had bilateral IMA grafts. The majority of patients had triple vessel disease (60%; 600 out of 1000) and 34% had double vessel disease (341 out of 1000). Graft conduits consisted of 70% IMAs, 28% radial arteries, 2% venous grafts, and 4 grafts were inferior-epigastric arteries. Eighty-six percent of the ICR group (120 out of 140 patients) had triple vessel disease. Demographics of the patient groups are shown in Table 1. Patients with ICR were older, had higher European System for Cardiac Operative Risk Evaluation (EuroSCORE) category, experienced more reoperative CABG, underwent off-pump procedures, and were less likely to have normal ejection fraction.

ICR Versus CR

CR was achieved in 801 out of 941 patients (85%) with multivessel disease and ICR occurred in 140 patients (15%). Significant predictors of ICR are presented in Table 2. The ICR group had less bilateral IMA grafting, more off-pump procedures, higher logistic EuroSCORE category, was more likely to have collaterals, was older, more patients with ejection fraction <30%, fewer outpatients, and more likely to undergo reoperative surgery. The numbers for very low ejection fraction and reoperation were small in both groups. No other cardiac risk factors or comorbidities were associated with ICR.